DTIC FILE COPY

(2)

US Army Corps of Engineers

AD-A213 111

INVESTIGATION OF THE IDA-RAISINVILLE SANITARY SEWER PIPE DISTRESS

by

R. E. Leach, G. S. Wang, G. B. Mitchell

Geotechnical Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road
Vicksburg, Mississippi 39180-6199

US ARMY ENGINEER WATERWAYS EXPERIMENT STATION

September 1989

Final Report

Approved For Public Release; Distribution Unlimited

GEOTECHNICAL LABORATORY

Prepared for US Army Engineer District, Detroit
Detroit, Michigan 48231-1027

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Miscellaneous Paper GL-89-21	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION USAEWES, Geotechnical Laboratory; 6b. OFFICE SYMBOL (If applicable) CEWES-GS-S	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) 3909 Halls Ferry Road Vicksburg, MS 39180-6199	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION USAED, Detroit; 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) Detroit, MI 48231-1027	10. SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Investigation of the Ida-Raisinville Sanitary Sewer Pipe Distress

12. PERSONAL AUTHOR(S)
Leach, R. E.; Wong, G. S.; Mitchell, G. B.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final report	FROM ____ TO ____	September 1989	40

16. SUPPLEMENTARY NOTATION
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Compaction; Cracks; Concrete pipe; Distress

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The US Army Engineer District, Detroit, oversees grants for the Environmental Protection Agency (EPA). However, with little inspection authority, the Corps is forced to conduct only limited inspection and sometimes only forensic study of potential problems. The Ida-Raisinville sanitary sewer project, funded as an EPA grant, was determined to be unacceptable only after the project was essentially complete and acceptance pressure tests were conducted. After failing pressure specifications, a TV camera survey was conducted and it was determined that there were a minimum of 100 cracks (mostly circumferential) in a section of the project comprising about half the total footage of installed sewer line. To put the sewer in service, it had to be determined whether the pipe failure was continuous, what the probable cause of failure was, and what would be a reasonable and economical repair scheme.

(Continued)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

DD Form 1473, JUN 86 — Previous editions are obsolete — SECURITY CLASSIFICATION OF THIS PAGE

Unclassified

19. ABSTRACT (Continued).

A second TV camera survey conducted 5 months later determined that there were no new cracks. This meant that the crack problem had occurred by the end of construction. The pipes had been certified by the manufacturer as passing both the pressure and strength specifications of a class of pipe better than the specified pipe, and postconstruction tests on contractor-discarded pipe again passed these same specifications. However, a visual inspection of the discarded cracked pipe did not show evidence that the visible cracks extended completely through to the inside of the pipe. The visual inspection seemed to indicate a handling problem by the manufacturer or the contractor. Inspection reports indicated that compaction in the trench was neglible and that in areas with a high water table, dewatering in the trench was not satisfactory. The failure to adhere to good construction practices for compaction and dewatering, outlined in the job specifications, could have aggravated an existing cracking problem or could have caused new cracking during placement. A more extensive forensic study was not recommended for the owner because of the time and money that would be expended and because the sewer line was obviously not satisfactory and the burden of proof of fault would lie with the contractor or pipe manufacturer. Several repair methods were recommended to the owner and it was left to the owner's discretion to balance the time and economics involved.

PREFACE

The study reported herein was sponsored by the US Army Engineer District, Detroit (NCE), under IAO No. NCE-IA-89-047 dated 5 May 1989. The investigation was conducted by the US Army Engineer Waterways Experiment Station (WES) during FY 1989.

The study was conducted under the direction of Dr. W. F. Marcuson III, Chief, Geotechnical Laboratory (GL), and under the general supervision of Mr. G. B. Mitchell, Chief, Engineering Studies Group (ESG), and Mr. G. P. Hale, Acting Chief, Soils Mechanics Division (SMD). Direction was also given by Mr. B. Mather, Chief, Structures Laboratory (SL), and general supervision was given by Mr. R. L. Stowe, Chief, Materials and Concrete Analysis Group (SV-M), and Mr. C. E. Gettinger, Chief, Concrete Technology Division (SC). The project engineers for the study were Mr. R. E. Leach, ESD, SMD, Mr. G. S. Wong, SV-M, SC, and Mr. G. B. Mitchell, ESD, SMD, and the report was prepared by the same. COL Larry B. Fulton, EN, is the Commander and Director of the WES. Dr. Robert W. Whalin is the Technical Director.

Contents

PART I: INTRODUCTION

Background

1. The investigation reported herein was precipitated by the failure of a sanitary sewer to meet air pressure specifications and by subsequent TV camera inspections that revealed numerous circumferential cracks along a large portion of the completed 12 inch reinforced concrete pipe section. The failed section is part of the contract for Monroe County, Ida and Raisinville Townships Sanitary Facilities Program Phase II, EPA No. C-262925-03, Contract I. Wade Trim and Associates, Inc. (WTA) prepared the contract documents and served as the consultant engineer to oversee construction for Monroe County. J. C. Harte & Sons, Inc. (JCHS) was awarded the contract and had finished most of the construction work in December 1988, before the acceptance tests were initiated.

2. Contract I is federally funded as an EPA grant and is located as shown in Figure 1. The US Army Engineer District, Detroit (NCE) is involved as an overall grants manager to administer the grant and to advise the EPA of problems that could arise due to plans and specifications or to the contractor's construction methods or negligence. The NCE involvement does not include daily construction inspection. The U.S. Army Engineer Waterways Experiment Station (WES) was asked to provide assistance for this project, Appendix A, in the areas of soil mechanics and materials properties. A trip report describing the initial meeting of WES with the owner (Monroe County), the owner's geotechnical consulting firm (WTA), and NCE personnel is presented in Appendix B.

Purpose and Scope

3. The purpose of this investigation was to review the available reports and data as an effort to establish or eliminate, if possible, causes for the failures in the 12-inch diameter reinforced concrete pipes. Determining probable cause or causes is attempted only to help insure that any corrective action chosen is feasible and/or final. Included are suggested methods for corrective action to give the owner the option to choose a viable alternative by which the system can be put into operation. The scope of this report is to review existing data, to discount failure possibilities using these data thereby reducing the number of possible causes to the minimum consistent with the data, to propose methods of repair, and to discuss what might be gained by a more extensive investigation.

PART II: TECHNICAL DATA SURVEY

Literature Cited

4. The following literature was furnished by NCE and reviewed for this report:

a. Wade Trim & Associates Daily Inspection Reports
   1. Volume 1: September 1988 through February 1989
   2. Volume 2: June 1988 through August 1988
   3. Volume 3: March 1988 Through May 1988

b. Construction Testing Engineers, Concrete Pipe Certification of 12" dia pipe for Marsh Products Inc.

c. Certificate of Compliance for 15" dia Concrete Pipe for Marsh Products Inc.

d. Somat Engineering Inc., Retesting of 6 Lengths of 12" dia job rejected pipe

e. Geotechnical & Materials Consultants Inc., Subsurface Investigation Waste Disposal Facilities - Ida Township Sewers and Lagoons

f. Wade Trim & Associates and SOS Service Group Inc. Inspection and Repair Report, Dec - Jan 1988

g. Wade Trim & Associates, Preliminary Assessment of TV Inspection Report

h. Monroe County, Minutes of Progress Meetings

i. Bowser - Morner, Nuclear Density Determination on Completed Ida Township Project

j. Monroe County, Plans and Specifications for the Ida and Raisinville Townships Sanitary Facilities Program Phase II, Contract I & II

k. Monroe County, Contract Documents for Ida and Raisinville Townships Sanitary Facilities Program Phase II, EPA No. C-262925-03, Contracts I & II, Prepared by Wade Trim & Associates, Inc.

l. France Stone Company, Gradation Sheets for 3-4-8 Aggregate for Cover Backfill, January - December 1988

m. Somat Engineering, Inc., Ida-Raisinville Townships Sanitary Facilities Program Field and Laboratory Reports:

1. Volume 1. Compaction Reports

2. Volume 2. Laboratory Sieve Analyses, Laboratory Factors

n. Wade Trim & Associates, Letter to Commissioner Burton in response to Mr. Maloney's (NCE) Letter, May 12, 1989, requesting further information.

Statement of the Problem

5. During the period of March through December 1988, the contractor, (JCHS), installed approximately 17000 feet of sanitary sewer for the Monroe County Sanitation District. The pipe mix was 12 inch and 15 inch reinforced concrete, and 8 inch and 6 inch PVC pipe. Upon completion of installation of the pipe, contract specifications required that the system pass a pressure test and that a TV camera video of the inside of the pipe be recorded before the system could be put into service. On December 16, 1988, a pressure test on the 8 inch PVC pipe was conducted and the system passed. On December 20, 1988, a pressure test on the 12 and 15 inch concrete pipe was conducted and the system failed to hold the required pressures. The TV camera inspection was started on December 22 in the 12 and 15 inch concrete pipes and was finished on January 3, 1989. Initial inspection by WTA of the TV camera work in progress indicated there were open joints and numerous circumferential cracks in the pipe some of which allowed streams of water to flow into the pipe. A later survey of the video tapes confirmed the initial findings and a synopsis is shown in Table 1.

PART III

DISCUSSION

Subsurface Soil Description

6. A subsurface soil investigation was conducted by Geotechnical & Materials Consultants, Inc. and is included in the project plans and specifications. Soil profiles generated from the subsurface investigation for Ida Road and Lewis Avenue are shown in Figures 2 and 3. Soil layering in this area generally is clay at the surface, followed by a fine sand with silt, which is underlain by cobbles and/or rock. The clay layer ranges in color from brown to gray and is described as stiff to extremely stiff. The sand also ranges in color from brown to gray and is described as compact and fine grained with traces of silt, coarse sand, and gravel. The water table in this area, Figures 2 and 3, was measured in the borings that intercepted the sand layer while none was apparent, during this study, for the borings that stopped in the clay or went through clay and met refusal in the rock layer. The water table ranges from 8 to 13 feet above the bottom of the trench excavated for the sewer pipe. The construction inspector, supplied by WTA for the owner, also noted problems with water standing in the trenches or with extremely wet conditions at or near the manholes shown in Figure 4.

Possibilities Contributing to Failure

7. Although the list of possibilities or combination of possibilities contributing to failure can never exactly be established, the following factors should be considered:

a. Pipe properties. This would include concrete properties, manufacturing practice, and acceptance testing of the invoiced pipe.

b. Soil conditions. This would include existing conditions as determined by a soil investigation, changed conditions caused by excavation of the trench in the material, properties of the bedding material, and compaction of the bedding and backfill material.

c. Construction practices. This would include the contractor's ability to excavate the trench without causing a deteriorating condition or his ability to stabilize conditions. Since differential movement would be detrimental, compaction of the pipe bedding and pipe leveling practices are critical to avoid settlement.

Trench Foundation and Bedding Properties

8. As shown in Figures 2 and 3, approximately 75% of the trench bottom, where cracks occurred is located in material that is classified as fine sand with traces of silt, coarse sand, and gravel. The remainder of the trench bottom was cut into a stiff to very stiff clay with only traces of sand and silt. After excavation the bottom of the trench had the equivalent of 8 to 13 feet of head acting upwards due to the high water table. The system used to remove the water from the trench has been described to have been by pumping through pipes extending to the bottom of the trench. The construction inspector noted the contractor was pumping from a "deep well" at Manhole No. 10. If the water was simply pumped out of the bottom of the trench, there existed the possibility of a quick or unstable condition occurring in the fine sands due to the uplift pressures acting on the bottom of the trench. The clays would not become quick but could become soft if water was allowed to stand in the trench for very long. The specifications require that the area be dewatered before commencing any construction activity and that dewatering be maintained where the work area will remain in a dry condition (pg 2.01-1).

9. The bedding material was brought in and placed in the bottom of the trench to provide a flat surface suitable for establishing specified grade for the installation of the pipe. This material along with the foundation materials when properly prepared should also assure that there was a minimum of differential movement along the base of the trench at the time of installation and later as the backfill was being added and compacted. The gradation of the bedding material is shown in Figures 5 and 6. The bedding stone, Figure 5, was a coarse material ranging from 3/4 inch down to 3/16 inch rock with less than 5% material below this size. The crushed limestone, Figure 6, ranged from approximately 1 inch down to 1/16 (No 10 sieve) inch with 25 to 50% of the material below this size. Also shown in Figures 5 and 6 are the grain size curves for the fine sand which comprised around 75% of the trench foundation material. Generally the bedding stone would not meet filter criteria for retention of the foundation sand if flow occurred or if pumping occurred from the vibratory compactor during backfill compaction. The crushed limestone would meet the criteria if segregation or bunching of the material was not allowed to occur.

Compaction

10. A review of all the compaction tests performed during and after construction indicated that of the hundreds of tests conducted only one was performed within 2 feet (above) of the pipe. In general the first compaction tests were conducted approximately 5 feet or more above the installed pipe. It was also noted by the construction inspector (Ref A) and the compaction inspector (Ref M) that lifts as thick as 4 to 7 feet were put into the trench before any type of compaction was attempted. Specifications cited the Controlled Density Methods in MDOT Section 2.08 was to be used (except as noted) which allows a layer of granular backfill to be up to 15 inches thick if 95 percent density can be obtained.

11. John Barber (WTA) stated, "No special procedure was utilized by the contractor to prepare the foundation of the sewer line prior to placing the bedding material, other than excavating to the desired grade. If unsuitable material was encountered, the contractor removed the unsuitable material and replaced it with crushed stone.

[[Contract Specifications: unsuitable existing ground conditions - where it becomes impossible to maintain alignment and grade properly, the contractor shall excavate and refill with aggregate or concrete approved by the engineer, pg 2.03-2]] Compaction tests were not specified nor performed on the bedding material. Normally, compaction testing on the bedding material is impractical due to the placement thickness (minimum four (4) inches) of the material and the depth of the excavation. The physical properties of the material specified for bedding are expected to attain its maximum density without significant compactive effort. Normally, the placement methods provide adequate compaction results.

12. Unsuitable material, however, was encountered on Lewis Street from Manhole No. 7 to Manhole No. 10 and on Ida East Road from Manhole No. 10 to Manhole No. 12. The sewer trench was undercut between four to 24 inches in these areas and some other isolated areas."

13. In the ideal case the density of the bedding material should achieve sufficient density during placement whereby there would be no problems with alignment and grade. If there is any reason to suspect the foundation material is too loose or soft for whatever reason, there should be a compactive effort. The specifications state that the trench shall be of sufficient width to provide adequate working space to permit the installation of the pipe and the compaction of

the bedding material under and around the pipe (pg 2.03-1). All unsound material underlying proposed structures shall be removed and replaced....and shall be compacted to 95% of maximum density unless indicated otherwise..... (pg 2.02-1).

14. Attainment of alignment and grade of the pipe requires that bedding material be shaped to allow the bell or spigot to be located properly. Shaping in turn requires that bedding stone beneath the pipe be in contact with the pipe for the full length or a bridging effect is established. The bridging allows the pipe to be subject to flexural loads, from the backfill and the compactive effort, which could crack the pipes.

TV Camera Survey

15. The results of the January 1989 camera survey, for the cracked sections, are tabulated in Table 1. The cracks were all described as circumferential cracks or joint leaks and it was thought that the cracks occurred at the mid point of the 8 foot long section. Upon further review it was noted that the cracks were at different distances from the joints. This was confirmed by visual inspection of the 29 pipes that had been discarded during construction due to circumferential cracks, cracked bells, and cracked spigots.

16. After reviewing the original TV camera survey, it was recommended that a resurvey be made of at least a portion of the worst distress. This survey was completed for the Ida East/West Road on 25 May, 1989 and supplied to the NCE on 2 June. The object of this survey was to determine if the cracking was a continuing phenomenon five months after installation or if all the cracking had occurred during installation. A review of the original versus the recent tapes showed that as well as could be established the cracking is not continuing with time. It was also noted in the recent tapes that some of the cracks, although circumferential, only traversed half the circle and others noted as cracks were short cracks or pinholes but leakage was occurring through them.

PART IV

MATERIAL AND REPAIR EVALUATION

Pipe Material Evaluation

17. Bell and spigot concrete sewer pipes with a class IV requirement and a type B wall according to ASTM C76 "Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe" were specified for the project. WES was told at the meeting, Appendix B, that Marsh Products, Inc. supplied the pipes usually provides pipes of the next higher class. Class V was indicated by the Certification Test Report by Construction Testing Engineers (CTE) in which the material was rated against ASTM Specification C-76-5-B. The specified class IV pipe has a D-load to produce a 0.01-in. crack of 2000 psi, a D-load to produce ultimate load of 3000 psi, and concrete strength of 4000 psi. D-load is expressed in pounds-force per linear foot per foot of diameter and was determined according to ASTM C497 "Standard Methods of Testing Concrete Pipe, Manhole Section, or Tile".

18. Data from tests by CTE and certificate of compliance from Marsh Products, Inc. (references B and C) were reviewed along with retest of pipes by Somat Engineering, Inc. (SE) (reference D). The reports show that the 0.01-in. crack test exceeded required load in excess of 20 percent of that required for class V-B which is 50 percent higher than that for class IV-B indicating that D-load was almost twice that needed to meet specification. Only two data points, tests of lot 88-70 and 88-73 were provided with actual loads of 4375 and 4675 lbs/foot, respectively. All other results were given as a footnote "Exceeded required load for 0.01" crack in excess of 20 percent."

19. The retest by SE were made in November 1988 of pipe samples from five different lots with one pipe of unknown lot origin. All D-loads to produce a 0.01-in. crack were greater than 2000 lbs/ft. D-load to produce ultimate load actual ranged from 5500 to 7428 lbs/ft. which also exceeded D-load specified to produce ultimate load. The concrete pipe tested ranged from about 4 to 7 months in age from when manufactured. The maturing process would increase the overall strength in the concrete from the original strength tested within a few days of fabrication. Based on the limited information we cannot speculate on the properties of the concrete at the time it was installed.

20. The presentation of the data in the reports reviewed was not conducive for tracing the maturing process since the information provided for the D-load to produce 0.01-in. crack was a pass/fail criteria. In many instances the test was stopped when the test exceeded certain limits beyond which the specimens is considered passing. Only the D-load to produce ultimate actual load were given for two original tests, lots 88-70 and 88-73. The range of 5625 to 6875 lbs/ft. is comparable with the values shown in the post-compliance tests giving some indication that the quality of the concrete has not changed significantly since its original production.

21. SE also tested six samples consisting of three cores for compressive strength and absorption. Compressive strength had an average range of 5701 psi to 7213 psi with an average absorption range of 4.26 to 4.96 percent. Concrete strength requirements were 4000 psi and absorption requirement, Method B, was a maximum of 8.5 percent showing that these two physical properties both exceeded the requirements for class IV-B concrete pipe.

22. Although quality control was being practiced, the initial crack that was found that led to a rejected pipe was discovered after water from a rain left a visible moist area along the crack as the rest of the pipe dried. The cracks were evidently hairline cracks and numerous pipes may have been installed before the cracking problem was discovered. Inspection findings, 12 May 1989, of pipes rejected at the project site were reported in a letter to Monroe County Drain Commissioner from WTE, dated 25 May 1989. Of the 23 pipes remaining on the site available for inspection, 10 contained exterior cracks with two having evidence of continuation of cracks into the interior of the pipe, Table 2. Review of some of the recent video tapes of Ida Road pipe show some pinhole type openings leaking water into the pipe. Other deficiencies include some partial lateral type cracks similar to the circumferential cracks only not visible the entire circumference of the pipe.

23. Review of all available data on the concrete pipe show that the invoiced pipes exceeded the requirements for the pipe specified for this project. The quality of the pipe although exceeding the specification may have had some manufacturing flaws in some pipes as indicated by the rejected pipes and the pinholes observed in some of the installed pipes. It is not possible to tell if the circumferential cracks observed in the installed sewer pipes are manufacturing flaws

or flaws caused by transit around the yard or to the site or by handling at the site. Examination of the concrete in the installed cracked pipes may shed light on the cause if the compression and tension areas of the cracks can be determined to be associated with possible features in the foundation.

24. Vibratory compactors used on the project to compact the fill material were described only as a "HO-PAC" (Trademark) which are hydraulically operated and can be attached to backhoe equipment. Informational literature shows that with factory baseplates the 8700c and the 9700c produce 6400 lbs and 13,500 lbs of force, respectively. The flexural load capacity of the pipe was not determined as part of the certification but it can be determined using a 2-dimensional finite element analysis or some actual flexural testing of some similar pipes in a test bed. Because of the complexity of the loading it would be difficult to do simple hand calculations that would be meaningful. It is felt that improper bedding preparation combined with the loads indicated for the compaction device and the overburden loads[1] can be one possible cause of the circumferential fractures noted in the pipes.

Repair Method Evaluation

25. There are several methods of repair and rehabilitation that can be considered to put the sewer line into service. The methods are listed below:

a. Use the sewer line as is and make repairs on those sections as they become unserviceable.

b. Replace those sections that are currently defective and are considered unserviceable.

c. External grouting of the fill around the pipe is not feasible using portland cement grout due to excessive fines in the fill. Sieve analysis of the bedding stone indicate that some of the material had as much as 50 percent passing the 3/8-in. sieve and over 10 percent passing the No. 200 sieve. The use of chemical grout may be possible as chemical grouts are less viscous and will penetrate materials with a finer gradation.

d. There is a possibility of sealing the cracks remotely from the inside using a chemical grout and a double packer set-up with a packer being placed on either side of a crack or leaking joint and the chemical grout pumped into the pipe

---

[1]1. Effects of Loads on Buried Pipes, Department of the Army, Corps of Engineers, January 1960.

and into the cracks or joints. As in most grouting operations, the uniformity of the operation depends on the condition of each joint: if the crack is active, if the crack is open or closed, if the crack is wet or dry, and if the crack is producing flow. Avanti (713-554-7541) and Leak Repairs (/13-331-6154) both of Houston, Texas can provide information on chemical grout repairs.

e. Link-Pipe, Inc. markets a system that repairs the joints and cracks from within the pipe using a sleeve type system sealing each joint or crack individually. The system will reduce the diameter of the pipe where it is installed and does protrude from the pipe wall an estimated 3/8-in. causing turbulence during flow. The reduction in diameter and added turbulence will cause reduced flow capacity. Link-Pipe, Inc. of Ontario, Canada (416-886-0335) can provide information on the sleeve system.

f. Insituform is a process where a new pipe is formed within the old existing pipe. The whole pipe can be lined in one operation. The Corps has adopted a modified Insituform technique in making water stop in large hydraulic structures which was reported in Vol. 2, No. 3 of the REMR Bulletin dated September 1985. Further information can be obtained from Insituform North, Inc., P.O. Box 250, Owosso, Michigan, 48876 (Ph 517-725-9525).

26. Any of the techniques mentioned can be used by itself or in combination with other techniques depending on the project needs. The grouting techniques seem to have the most uncertainty associated with them in that there seems to be no positive assurance that the leaks will be sealed nor how effective the grout is in restoring structural integrity.

PART V

SUMMARY

27. The purpose of this investigation was to review the available data to establish, if possible, a probable cause for the cracking in the 12 inch reinforced concrete sewer pipes and to recommend methods that could be used to place the line in service. The purpose of this report is not meant to establish blame but to try to insure the owner that their selected rehabilitation scheme will be as permanent as state-of-the-art can supply. Extensive excavations, observations, and tests would be required for more definitive causes.

28. The review confirms that the cracks in the pipes were present by the end of construction as indicated by the failed pressure tests and the TV camera video tapes but it is not as apparent as to when the cracks were caused. The subsequent video of Ida Road in May 1989, approximately 5 months after construction, indicates that the cracking is not continuing with time. Visual inspection by WTA of 23 job rejected pipes showed evidence of cracking in pipes that had not been placed in the trench but that had been delivered to the site as material which passed the standards for Class V pipe. In two pipes the cracks could be visually observed from the inside of the pipe. The testing standards used for these pipe did not require a flexural strength test and pipes with hairline cracks could pass pressure, absorption, and compression tests.

29. Soil and water conditions in the trench during construction were not ideal for pipe placement. As noted by the construction inspector there were numerous times when water was standing in the bottom of the trench when the specifications called for dewatering to dry conditions. Also unsuitable soil had to be removed in several areas and compaction of the foundation or bedding material was not attempted. These conditions and other construction procedures, i.e., attempting to obtain compaction of the backfill, shaping of the bedding stone, compaction under and around the pipe, could lead to differential settlement of the pipe. Settlement could cause expansion of existing cracks or possibly could cause new cracks. Settlement of the pipes should be complete for the construction phase but settlement of the <u>backfill</u> is possible, depending on the degree of compaction. If excavation and recompaction of the backfill near the pipes becomes necessary, care should be exercised to prevent further damage to the pipes.

30. The possible causes of the cracking are some or all of the following:

a. cracked at factory, handling in transit and during installation

b. inadequate shaping and compaction of the bedding material

c. inadequate compaction under the pipe

d. over compaction above the pipe.

The methods of repair stated in the evaluation section will allow the owner to put the failed lines into service. The least obtrusive repair will give the maximum flows in the line and will be the easiest to bypass for future maintenance. Suggestions dated 1 January 1989 and contained in Reference F seem to be a reasonable solution for getting the sewer line in service. Complete replacement of the cracked pipes would of course be the best repair but economics and time may require that a combination of replacement and repair be employed and it is beyond the scope of this report to determine the most feasible solution.

TABLE 1

VIDEO TAPE REVIEW

Wade-Trim/Associates
Member of the Wade-Trim Group
25185 Goddard Rd. • P.O. Box 10 • Taylor, MI 48180
313-291-5400 • 800-482-2864

WORK SHEET

IDA - RAISINVILLE

OUTLET	JOINT LEAK	CRACKS	CRACKS W/LEAK	SERVICES W/LEAK	OPEN JT	OFFSET JT	NO REPORT
EX MH TO MH#1							
MH#1 TO MH#2	1						
LEWIS AVE.							
MH#2 TO MH#21							
MH#2 TO MH#3							
MH#3 TO MH#4							
MH#4 TO MH#5	2						
MH#5 TO MH#6							
MH#6 TO MH#7		3					
MH#7 TO MH#8		2					
MH#8 TO MH#9		2		2			
MH#9 TO MH#10		4	2	2			
MH#10 - MH#11		3	3				
IDA EAST RD.							
MH#11 TO MH#12		3		1			
MH#12 TO MH#13			2				
MH#13 TO MH#14		2	2				

SUBJECT	BY	CHK.	SHEET NO.	JOB NUMBER
TV EVALUATION (PRELIMINARY)	JNB DATE 1-6-89	DATE	1 OF 5	MOD. 2003.06

(Continued)

TABLE 1 (Continued)

Wade-Trim/Associates
Member of the Wade-Trim Group
25185 Goddard Rd. • P.O. Box 10 • Taylor, MI 48180
313-291-5400 • 800-482-2864

WORK SHEET

	JOINT CRACK	CRACKS	CRACKS W/LEAK	SERVICES W/LEAK	OPEN JT	OFFSET JT	NO REPORT
IDA EAST (CONT.)							
MH #14 TO MH #15		7	1				
MH #15 TO MH #16		10					
MH #16 TO MH #17		9	1				
WESTWOOD DR.							
MH #4 TO MH #24					1(L)		
MH #24 TO MH #25					2		
MH #25 TO MH #26							
NORTHWOOD DR.							
MH #24 TO MH #27							
EASTWOOD DR.							
MH #27 TO MH #28							
MH #28 TO MH #29							
MH #29 TO MH #30							
SOUTHWOOD DR.							
MH #30 TO MH #31							

SUBJECT TV EVALUATION (PRELIMINARY) | BY JWB | DATE 7-6-89 | CHK. | DATE | SHEET NO. 2 OF 5 | JOB NUMBER MOD • 2003 • 06

(Continued)

TABLE 1 (Continued)

Wade-Trim/Associates
Member of the Wade-Trim Group
25185 Goddard Rd. • P.O. Box 10 • Taylor, MI 48180
313-291-5400 • 800-482-2864

WORK SHEET

	JOINT CRACK	CRACKS	CRACKS W/LEAK	SERVICE W/LEAK	OPEN JT	OFFSET JT	NO REPORT
IDA ST							
MH#6 TO MH#32			/				
MH#32 TO MH#33					/		
MH#33 TO MH#34					/		
MH#34 TO MH#35							
MH#35 TO MH#36					/		
MILL ST.							
MH#33 TO MH#37							
MH#37 TO MH#38							
MH#38 TO MH#39							
VAN AIKEN ST.							
MH#8 TO MH#41							
MH#41 TO MH#42							
MH#42 TO MH#43				/		/	
MH#43 TO MH#44				/			
PRAIRIE ST.							
MH#34 TO MH#40					/		

SUBJECT: TV EVALUATION (Preliminary) | BY: JWB | DATE: 1-6-89 | CHK.: | DATE: | SHEET NO. 3 OF 5 | JOB NUMBER: MOD • 2003 • 06

(Continued)

TABLE 1 (Continued)

Wade-Trim/Associates
Member of the Wade-Trim Group

25185 Goddard Rd. • P.O. Box 10 • Taylor, MI 48180
313-291-5400 • 800-482-2864

WORK SHEET

	JOINT LEAK	CRACKS	CRACKS W/LEAK	SERVICE W/LEAK	OPEN JT	OFFSET JT	NO REPORT
SOUTHWICK ST.							
MH#42 TO MH#45							1
LEWIS AVE (N. OF IDA E.)							
MH#10 TO MH#46							
MH#46 TO MH#47			1				
MH#47 TO MH#48		3	1				
MH#48 TO MH#49		3		1			
MH#49 TO MH#50		2		3			
MH#50 TO MH#51		5					
MH#51 TO MH#52		1	1				
MH#52 TO MH#53		1	1				
IDA WEST RD.							
MH#46 TO MH#60	1	5	3				
MH#60 TO MH#61		6	4				
MH#61 TO MH#62		5	1				
ELM ST.							
MH#49 TO MH#57							1
AK ST.							
MH#50 TO MH#59							1

SUBJECT: TV EVALUATION (PRELIMINARY) BY: JNB DATE: 7-6-89 CHK. DATE SHEET NO. 4 OF 5 JOB NUMBER MOD • 2003 • 06

(Continued)

TABLE 1 (Concluded)

Wade-Trim/Associates
Member of the Wade-Trim Group

25185 Goddard Rd. • P.O. Box 10 • Taylor, MI 48180
313-291-5400 • 800-482-2864

WORK SHEET

	JOINT LEAK	CRACKS	CRACKS W/LEAK	SERVICE W/LEAK	OPEN JT.	OFFSET JT	NO REPORT
RIGGS ST.							
MH#62 TO MH#63							(1)
SOUTHWICK ST. (N.)							
MH#61 TO MH#64							(1)
MH#64 TO MH#65					1		
TOTALS	4	76	24	11	8	1	5

NOTE: THIS PRELIMINARY REPORT WAS COMPILED FROM THE IDRs AND NOT FROM REVIEWING THE T.V. TAPES. A FINAL DETERMINATION CANNOT BE MADE UNTIL AFTER THE TV TAPES HAVE BEEN REVIEWED.

SUBJECT	BY	CHK	SHEET NO.	JOB NUMBER
TV EVALUATION (Preliminary)	JHB DATE 1-6-84	 DATE	5 OF 5	1100 • 2003 • 06

TABLE 2

VISUAL INSPECTION OF REJECTED PIPE

Wade-Trim/Associates
Member of the Wade-Trim Group
25185 Goddard Rd • P O Box 10 • Taylor, MI 48180
313-291-5400 • 800-482-2864

WORK SHEET

PIPE NO.	REMARKS
1	CHIP IN SPIGOT END OF PIPE
2	WYE PIPE, PARTIAL SAW CUT 1.8 FT. FROM SPIGOT END
3	WYE PIPE, COULD READ MARKING - "AIR TEST"
4	CRACKED SPIGOT END
5	WYE PIPE, CRACKED SPIGOT END, EXTERNAL CRACK AT MID-POINT, NO EVIDENCE OF INTERNAL CRACK
6	WYE PIPE, CHIP IN BELL END OF PIPE
7	EXTERNAL CRACK 2.5 FT. FROM BELL END, NO EVIDENCE OF INTERNAL CRACK
8	EXTERNAL CRACK AT MID-POINT OF PIPE, NO EVIDENCE OF INTERNAL CRACK
9	EXTERNAL CRACK AT MID-POINT OF PIPE, NO EVIDENCE OF INTERNAL CRACK
10	BROKEN SPIGOT END, COULD READ MARKING - "AIR TEST"
11	WYE PIPE, CRACK AT MID-POINT OF PIPE, NO EVIDENCE OF INTERNAL CRACK
12	WYE PIPE, CRACK AT MID-POINT OF PIPE, NO EVIDENCE OF INTERNAL CRACK
13	NO DEFECTS VISIBLE
14	WYE PIPE, CRACKED AT 3.5 FT. FROM SPIGOT
15	CHIP IN SPIGOT END OF PIPE
16	NO DEFECTS VISIBLE
17	CRACKED BELL
18	5.0 FT. SECTION OF PIPE, REMOVED RUBBER GASKET FROM PIPE
19	BROKEN SPIGOT END, CRACK 2.5 FT. FROM BELL END, NO EVIDENCE OF INTERNAL CRACK
20	CRACK 2.5 FT. FROM BELL END, THESE IS EVIDENCE OF INTERNAL CRACK AT 2.5 FT.
21	5.5 FT. SECTION OF PIPE, WALL THICKNESS MEASURED AT 0.2 FT
22	CRACK 2.5 FT. FROM BELL END, THERE IS EVIDENCE OF INTERAL CRACK AT 2.5 FT
23	2.5 FT. SECTION OF PIPE

SUBJECT	BY / DATE	CHK / DATE	SHEET NO	JOB NUMBER
VISUAL INSPECTION OF RCP	BY JHB, DATE 5-12-89		1 OF 1	MDO • 2003 • 11

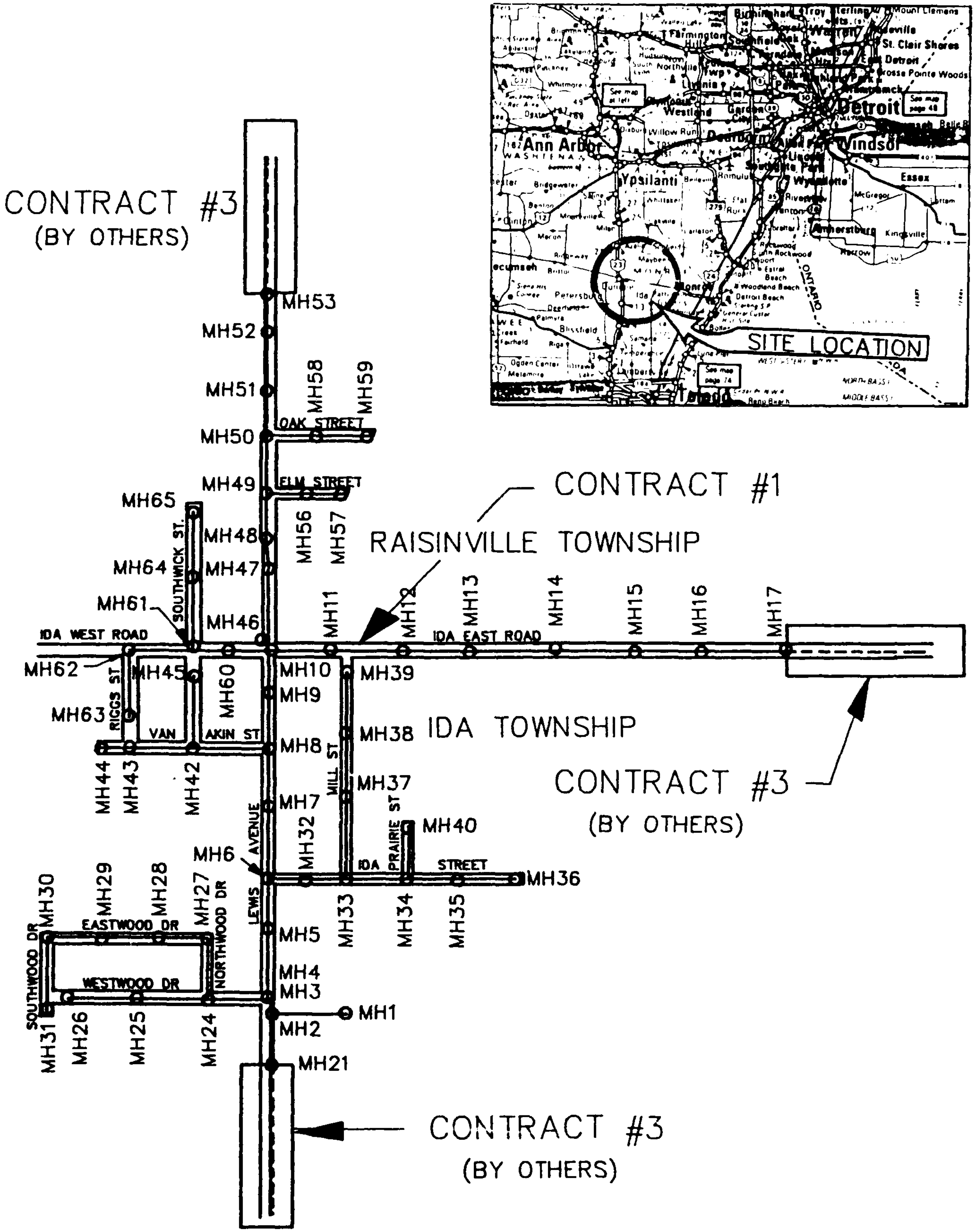

Figure 1. Site Location and Plan Map

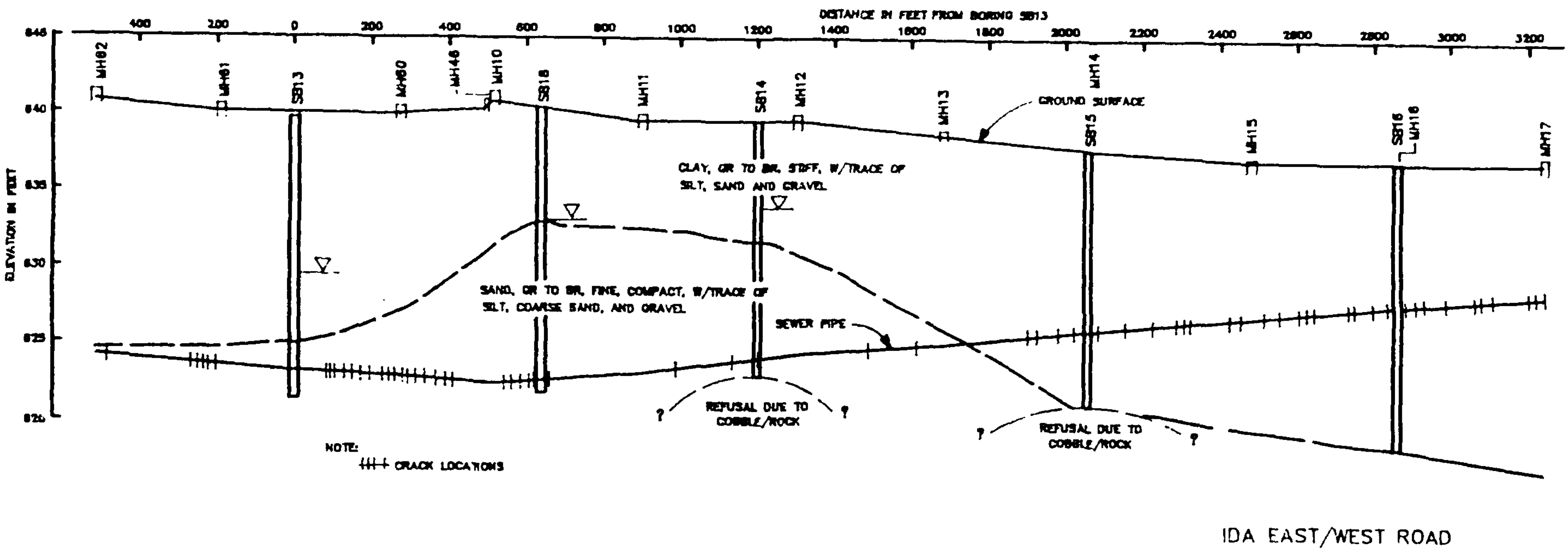

Figure 2. Soil Profile and Crack Location on Ida Road

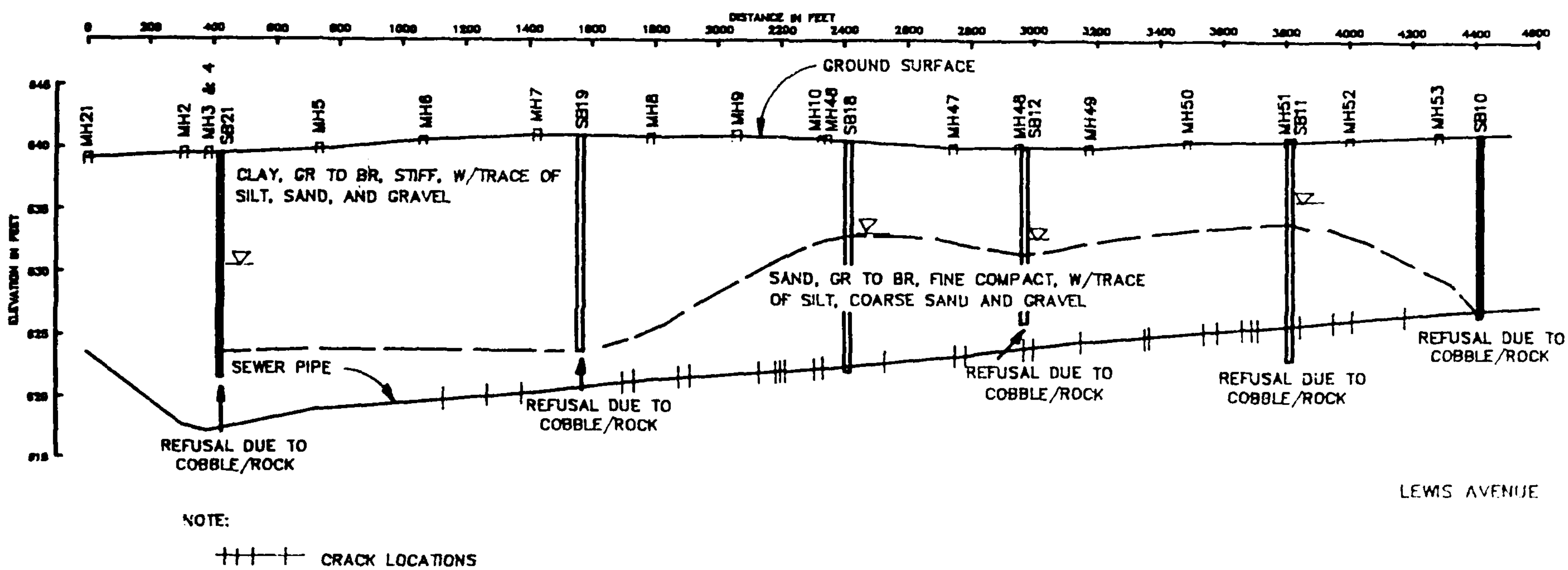

Figure 3. Soil Profile and Crack Locations on Lewis Avenue

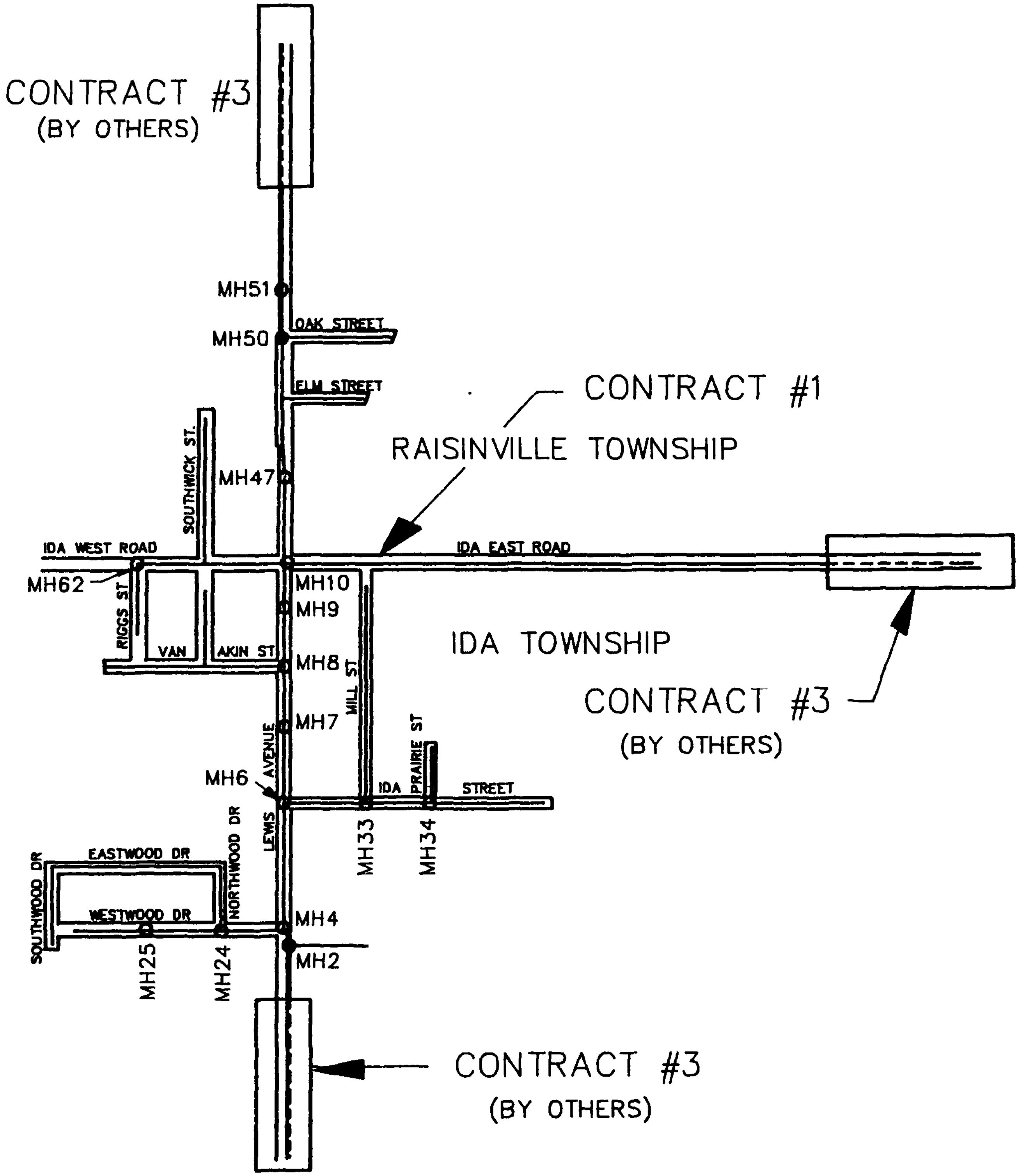

Figure 4. Site Plan Showing Manholes with Ground Water Problems

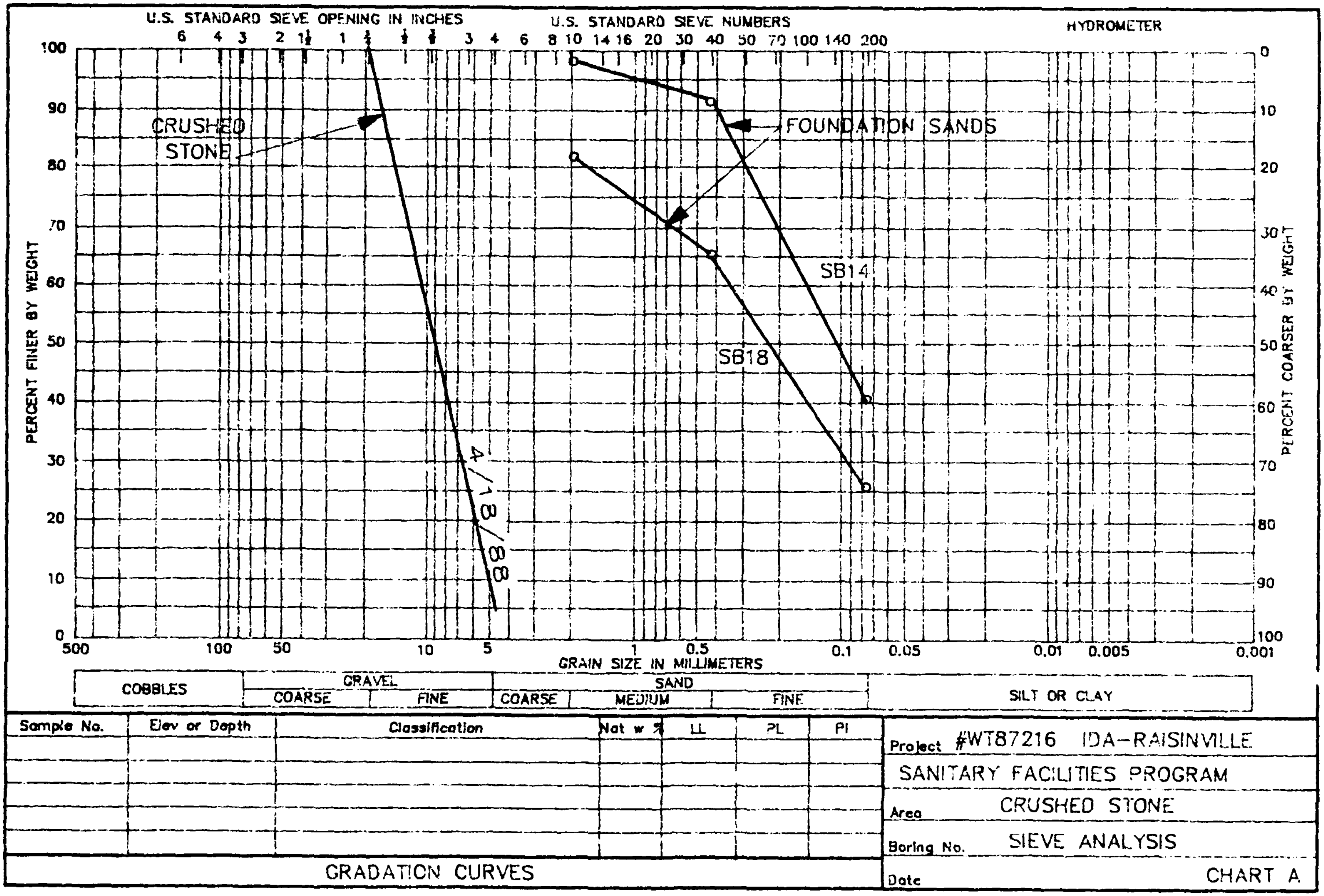

Figure 5. Grain Size Curve for Crushed Stone and Foundation Sands

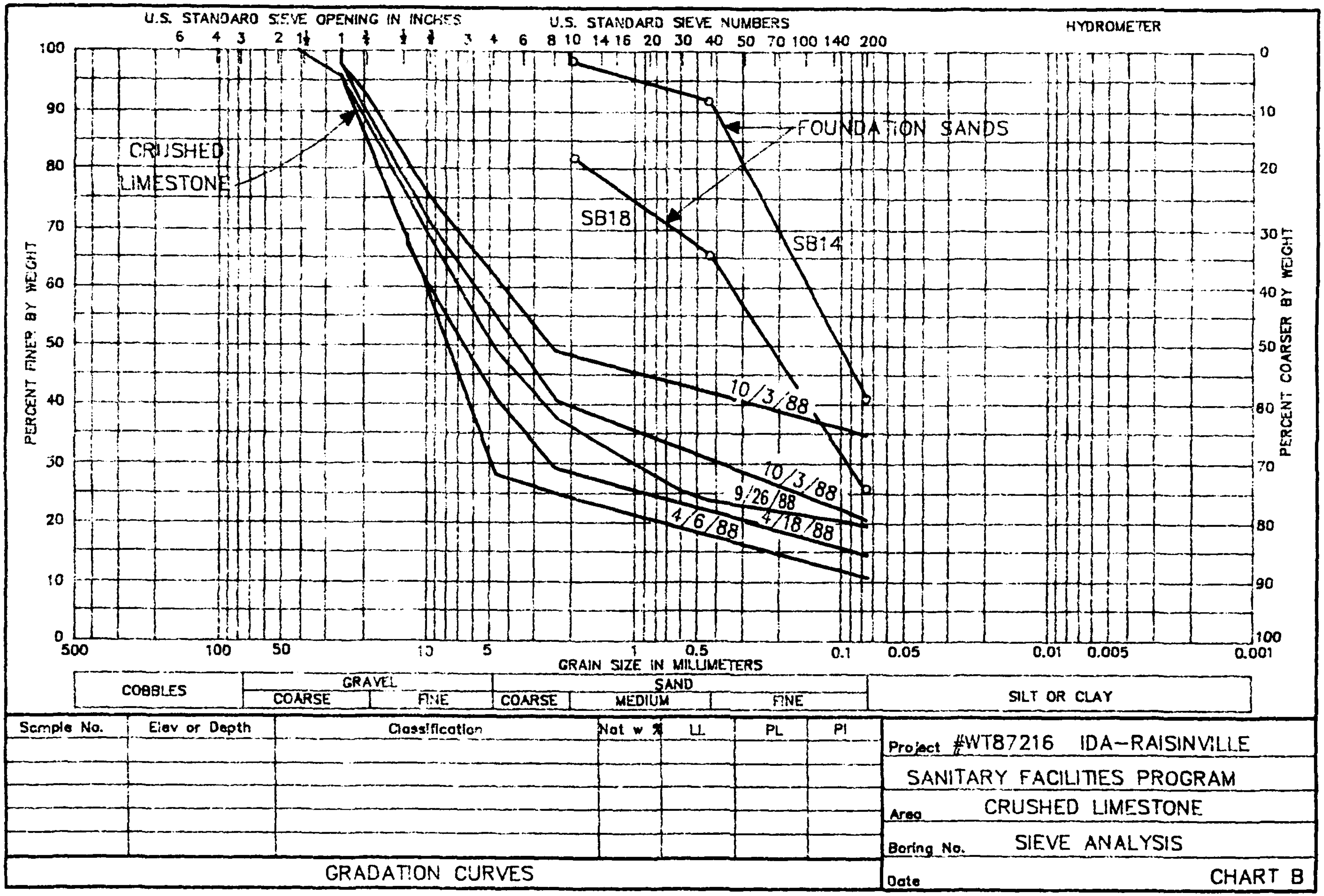

Figure 6. Grain Size Curve for Crushed Limestone and Foundation Sands

APPENDIX A
TELEPHONE CONVERSATIONS

CEWES-GS-S (340d) 19 Apr 89

MEMORANDUM OF TELEPHONE CONVERSATION

SUBJECT: Detroit Sewer Pipe Distress

1. Person called: Britt Mitchell, CEWES-GS-S, (601) 634-3640. Person calling: Sam Nakib, CENCD-OP, (312) 353-7850. Date called: 18 Apr 89.

2. I worked with Sam on the "15 Mile Road/Edison Corridor Sewer Tunnel Failure Study, Detroit Area, Michigan," in 1980. The study was for the Detroit District and concerned an EPA project. Another sewer project by the Detroit District for the EPA has experienced problems.

3. The new project includes about 17,000 feet of 8 to 12 diameter concrete sanitary sewer pipe that has recently been installed and is not yet in service. As is customary, the final inspection is made by video camera. In this case, the inspection produced seven cassettes with a total viewing time of 14 hours. The distress Sam described is radial cracking of the pipes - not in every joint, but pretty general over the entire length. Since WES fielded a good team for the tunnel problem, Sam assumed we might do the same for this problem.

4. I told him to send me (or have Detroit do it) a tape showing typical cracks, some of us would look at it, and if we then felt we could help, we would give Detroit (EPA) a proposal. He said he would get back to me.

G. B. MITCHELL
Chief, Soil Mechanics Branch

CEWES-GS-S (340d) 25 Apr 89

MEMORANDUM OF TELEPHONE CONVERSATION

SUBJECT: Detroit Sewer Pipe Distress

1. Person called: Britt Mitchell, CEWES-GS-S, (601) 634-3640. Person calling: Mr. Suren, CENCE-OP, (313) 226-4549.

2. Reference phone conversation between Mitchell/Nakib dated 19 Apr 89. Suren called me to pursue WES assisting the Detroit District with the sewer pipe problem.

3. He is this date mailing the video tape discussed in the above reference. I got a few more details from Suren. He thinks the pipes have about 20 feet of cover and are below the water table - at least in places - since the tapes show water in the pipes. Apparently, no pipes have collapsed and Suren couldn't tell me whether they were concerned about effluent leaking out or water leaking in.

4. I told Suren I would get back to him next week.

G. B. MITCHELL
Chief, Soil Mechanics Branch

CEWES-GS-S (340d) 5 May 89

MEMORANDUM OF TELEPHONE CONVERSATION

SUBJECT: Detroit Sewer Pipe Distress

1. Person called: Earl Edris, CEWES-GS-S, (601) 634-3378. Person calling: Larry Maloney, CENCE-OP, (313) 226-6795. Date called 4 May 89.

2. Reference phone conversations between Mitchell/Nakib dated 19 Apr 89, and Mitchell/Suren dated 25 Apr 89. Larry called me concerning WES assisting Detroit District with the sewer pipe problem.

3. Larry indicated that the District wants to determine the causes of the cracks in the sewer pipe. To initiate this work Larry felt a meeting in the District office is needed. This meeting would provide the WES team the opportunity to review the test data, the inspection report, possibly meet with the consultant who performed the inspection, survey the site, and develop a test plan for this study. The District would provide money to cover the cost of this trip. I indicated that about $5K would probably be needed for travel and labor of two engineers to travel to Detroit for a one day meeting. Larry had no problems with the money aspects and would send a 2544 when the costs are finalized. The District would like to have this meeting as soon as possible, preferably next week. I told Larry that I would get back to him concerning dates and costs after discussing this with the engineers making the trip.

4. I got some more details concerning the pipe distress from Larry. He indicated that only the 12 inch diameter pipe is cracked, not the 8 inch or the 15 inch. Also, he indicated that all the cracks occurred in the middle is the pipe sections and that some testing of the pipe material was performed on samples of pipe that were not installed. The consultant used for inspection indicated that some of the extra pipe sections had hairline cracks on the outside of the pipe in the middle of the sections and that tests performed on this material met the specifications.

E. V. EDRIS, JR.
Soil Mechanics Branch

APPENDIX B

TRIP REPORT, 9 MAY 1989

CEWES-GS-S 25 May 1989

MEMORANDUM FOR RECORD

SUBJECT: Trip Report, Sewer Problem, USAE District, Detroit

1. Messrs. Roy Leach and G. Sam Wong of the USAE Waterways Experiment Station (WES) met with USAE District, Detroit (NCE) personnel on 9 May 1989 to discuss problems concerning USEPA Grant No. C262925-03 providing funds to the Ida/Raisinville Township in Monroe County for placement of sewer pipes. Failed air pressure tests and a followup video survey, December 1988 to January 1989, indicated the 12-inch diameter concrete sewer was cracked and that 100 cracks were visible in the initial review. Other installations such as the 8-inch PVC pipe, the 6-inch PVC service leads, and the 15-inch concrete pipe were not of concern at this time because only minor repairs are needed to put these lines in service.

2. The Michigan Department of Natural Resources and the Monroe County Drain Commission has requested the Corps of Engineers to review the problems encountered and recommend corrective action that will allow them to put the sewer lines in service.

3. Messrs. Suren Sukhtanhar and Basil Najar of the NCE provided Messrs. Leach and Wong the details of the project and the concerns of the Grantee (Monroe County). They provided for our review the following documents:

a. Seven video tapes of sewers identifying cracks in the sewer system covered by the contract No. 1 of the grant.

b. Plans and specifications including soil boring locations and profiles.

c. USEPA Official Grant File - Section 7/COE Inspection Reports.

d. Daily inspection reports of the Construction Inspector for Wade-Trim Associates (WTA), the consulting engineer hired by Monroe County to oversee the project.

e. Density determinations made after the project for sewer trench backfill, Ida, Michigan.

f. Minutes of the meetings (progress meetings with WTA).

g. Daily inspection reports of WTA and other related documents.

h. Some miscellaneous contract documents.

i. Video inspection and work report done by WTA.

j. Information received from Monroe County.

4. After perusing some of the documents we then met with Ms. Eve M. Avendt (Deputy Drain Commissioner, Monroe County, Michigan), Mr. William H. Bravnlich (Attorney for Monroe County), Mr. John W. Barber (WTA representative), and Mr. Larry Maloney (Chief, Construction Branch, NCE). Mr. Barber reviewed the construction effort based on his knowledge of the project. Ms. Avendt also gave her insight on the work for the project. The information reported at this meeting will be incorporated into the observations made during the review of some of the documents while at the Detroit office. Mr. Leach asked what was the WES role for this project and how will the WES be involved in future discussions? The work that we will be doing is not intended to determine who is at fault but to find out the cause of the cracking in the pipes and to help them identify reasonable measures for repair. The ultimate choice for repair may be dictated by the funding available rather than by which method will provide the best repair.

5. Mr. Barber explained that there are approximately 100 circumferential cracks in the 12-inch diameter concrete pipe throughout the project. A short section of concrete pipe does not contain cracks; this area was later identified as pipe from manhole (MH) MH-1 to MH-6. The cracks were identified from video tapes as damp lines inside the pipe or where water was flowing into the pipe. Some of the joints also were open and producing water. The cracks were generally in the middle of the 8-ft. length of pipe but Mr. Leach indicated that in viewing some of the tapes he also noticed cracks near the joints. Mr. Barber also thought that the suspected longitudinal cracks may have been produced early in the project and the cracking is not occurring presently.

6. A class IV pipe was specified for the project. Normal practice by the pipe supplier is to provide the next higher class of pipe and in this instance a class V pipe was supplied for the project. Mr. Barber said that a number of pipe sections were rejected at the site due to circumferential microcracks first observed after a rain when dampness outlined the cracks in the exterior of the pipes. He thought that the individual pipe sections had all been pressure tested prior to delivery to the site and when questioned he did not know if the cracks penetrated the pipe or were only surface cracks. Post recertification of some of the rejected pipes indicated the strengths were more than adequate to meet class V specifications.

7. Mr. Barber described the material that was originally specified for use as bedding material and backfill as a sand and pea gravel. In reviewing the documents we did not find this and will need to get this point clarified. A crushed limestone appeared to have been used as the bedding material. Two crushed limestone types were mentioned in the specifications; a crushed limestone designated as MDOT348 backfill and a bedding material passing 3/4-inch and retained on the No. 4 sieve. It was not apparent by examination of inspection reports what materials were used. Ms. Avendt indicated that the quarry owner said that the material did not meet specifications for a MDOT348 bedding stone. Some investigation will be needed to sort out what was used and what was specified.

8. Some of the bedding material was compacted while it was not certain that all was compacted. No test data for the bedding material or for the granular backfill material were available at the meeting. The only compaction data available were of soil backfill determined on material within ten feet of the surface, while the pipe was placed between fifteen and twenty feet deep. The compacted material was specified for 133 lbs. per cu. ft. which was 95 percent of Modified Proctor density determined in the laboratory. Testing of the material indicated that the backfill failed specifications, but as mentioned by Mr. Leach, the density of the material above the pipe will have little to do with the cracked pipe problem. Mr. Wong said that the determination of density for the granular material may require excavation and measurement of larger test samples than normally required for soil and that for quality control during construction, one way to assure a quality product is to monit r the consolidation effort. Some of the consolidation was made by running a dozer over the material while other compaction effort was made using a "Ho-Pac" compaction device. An effort is needed to determine the consolidation of the granular material and any possible additional settlement that may occur.

9. We proposed that the following be done:

a. A video survey be made of one of the distress areas to see if additional problems are occurring. The survey should include alignment data.

b. One or more of the rejected pipe sections be air pressure tested and examined for crack propagation at midpoint.

c. Obtain data concerning the granular fill, such as gradation, placement, compaction test results, etc.

d. WES can make a schematic of cracks and deficiencies and locate them on a diagram of the project.

e. WES can correlate crack patterns with any deficiencies found in the soil or foundation profiles at the elevation of the pipe placement.

f. WES can look at the construction and inspection records to determine possible correlation of construction sequences that might provide additional information on the cause of cracking.

g. WES can recommend soil borings and further tests to verify previous identification and test data.

h. Excavation of pipe in areas where replacement is a probable remedy and examine the pipe and test the materials to determine properties.

i. Look at the geology and foundation of the local area.

10. The basic plan of attack will be as follows:

a. Collect pertinent information.

b. Evaluate information.

c. Develop scenarios for failure and recommend methods for repair.

11. The following were considered for possible repair methods:

a. Insertion of sleeve.

b. Grout from inside.

c. Grout from outside.

d. Remove and replace.

e. Use a combination of the above.

Roy Leach
Soil and Rock Mechanics

G. Sam Wong
Materials and Concrete Analysis